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for the Behavioral and Social Sciences

Research Report 1536

Contributions of the U.S. Army Research Institute to the Training Technology Field Activity–Aberdeen

Angelo Mirabella

August 1989

U.S. ARMY RESEARCH INSTITUTE
FOR THE BEHAVIORAL AND SOCIAL SCIENCES

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This report summarizes ARI's efforts to develop training guidelines for improved acquisition, retention, and transfer of vehicle maintenance skills. The need for such guidelines has been documented in 10 major studies since 1964, including 4 by ARI. The results of these studies are also summarized. The studies show that performance failure rates for diagnostic, remove/replace, and adjustment tasks are very high for both novice and experienced vehicle repairers. For example, the false removal rate (good parts mistakenly removed) is about 42% of all removals.

The results of the Training Technology Field Activity (TTFA) projects summarized include various recommendations and guidelines for improving the training of vehicle repairers. One set of recommendations, for example, suggested ways to immediately improve the 63W10 course at the Ordnance School. The recommendations emerged from an onsite review of the entire 16-week course given to 63W10s at Aberdeen. One set of guidelines dealt with

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how to produce effective vugraphs for classroom instruction. Another set derived from a review of scientific literature on training provided general principles on how to develop effective instruction principles.

These results can provide a partial springboard for future research, development, and training technology transfer under a continuing TTFA program at the Ordnance school. Keywords:

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Training and Simulation

FOREWORD

The US Army Research Institute (ARI) in cooperation with TRADOC and its schools, performs research and development on ways to achieve more cost-effective training. In 1987 ARI joined with TRADOC and the US Army Ordnance Center and School (USAOCS) in a partnership at Aberdeen Proving Ground (APG), Maryland to identify and solve maintenance training problems. The partnership was defined by a memorandum of understanding (MOU) entitled "Establishment of a Training Technology Field Activity (TTFA) at the USAOC&S", and dated 10 May 1987.

The present report is the final result of that partnership. The work was carried out as part of Task 344 by a member of the Logistics Training Technologies Technical Area of the Training Research Laboratory in order to provide a concise summary of all the TTFA-Aberdeen projects done under task 344.

This and other products of the TTFA were briefed to the Deputy Assistant Commandant, USAOC&S, in October, 1988. It will be used to help develop model training instruction and plan additional TTFA projects at USAOC&S. Its value was recognized by MG Ball, Commandant, to USAOC&S, in a letter of appreciation to the author.

Edgar M Johnson

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Technical Director

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The research summarized in this report would not have been possible without the outstanding support and cooperation of many people at the Ordnance School and at TRADOC Headquarters. I especially appreciate the efforts of my counterparts, Jim Dees at Aberdeen, Maryland, and Dr. Millie Abell at TRADOC Headquarters, Fort Monroe. The support of the Wheel Vehicle Department at Edgewood was an example of superb cooperative RDT&E efforts.

CONTRIBUTIONS OF THE ARMY RESEARCH INSTITUTE TO THE TRAINING TECHNOLOGY FIELD ACTIVITY--ABERDEEN

EXECUTIVE SUMMARY

Requirement:

Summarize research on maintenance performance problems and describe preliminary efforts by the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) to address the problems through the Training Technology Field Activity--Aberdeen.

Procedure:

The author reviewed reports of eleven studies conducted during the past 25 years and five reports prepared by ARI under the TTFA-Aberdeen Program. He distilled data and conclusions from the reports and presented them in a series of tables and figures.

Findings:

1. Failure rates among both novice and experienced vehicle repairers are dramatically high and should be a matter of serious concern to the Army, e.g., the false removal rate (goods parts taken out) is about 42%. Yet, in spite of 25 years of evidence accumulated by the Army itself, the problems remain.

2. The TTFA-Aberdeen provides a significant opportunity to begin to systematically address maintenance performance deficiencies.

3. Under the TTFA program, the Army Research Institute has generated some preliminary recommendations and guidelines for developing training which will substantially improve skill acquisition, retention, and transfer for vehicle repairers.

4. These recommendations and guidelines are presented in the report in tables and figures.

Use of Findings:

1. The findings can be used immediately to improve training for vehicle repairers at the U.S. Army Ordnance School.

2. Although targeted to vehicle maintenance training, the findings can be generalized to other types of training.

3. The results described in this report can provide a spring board for continuing research, development, and training technology transfer under the TTFA-Aberdeen Program.

CONTRIBUTIONS OF THE ARMY RESEARCH INSTITUTE TO THE TRAINING TECHNOLOGY FIELD ACTIVITY--ABERDEEN

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1.0 INTRODUCTION

1.1 This summary report is the final one in a series of efforts for ARI in the two-year, TTFA -Aberdeen Program. The report explains what products we left to the program and how they can be used by the Army. I've distilled information and conclusions from 5 earlier reports. But to appreciate the need for these products and their potental usefulness, the reader needs to know what was done before, as well as during, the tenure of the TTFA to study maintenance performance deficiencies.

1.2 During the last 25 years, the Army has paid for at least 10 projects to assess vehicle maintenance performance (Table 1). These studies have repeatedly shown high failure rates across a variety of tasks, conditions, and assessment techniques. But until the advent of the TTFA-Aberdeen, the studies appeared to have had little impact on how the Army trains its maintainers. In 1979 ARI did successfully develop a computer technique for tracking maintenance performance (Maintenance Performance System), but it was not implemented (Harper et al, 1979). The TTFA-Fort Knox did develop a computer-based instruction (CBI) program in maintenance for use on MICCROTICCIT, and it has received some adoption (Graham et al, 1986). Now the TTFA-Aberdeen as shown in this report has provided useful products which are being implemented at the Ordnance School.

1.3 Significance of historical perspective

a. Various Army elements have repeatedly studied and verified the same set of maintenance performance shortfalls for 25 years. Follow-up needs to be conducted on the TTFA-Aberdeen result to ensure that the total TRADOC/ARI expenditures of $2 million will continue to pay dividends.

b. The problem of dealing with maintenance performance deficiencies is especially significant because the Army spends $22,000 per year (1988 dollars) to train an entry-level mechanic (Unpublished study by USAOCS). The total cost for 1500 students

per year in the 63W10 program at Aberdeen is $33,000,000. Historically high failure rates, along with emerging TTFA results suggest that the return on this training investment can be improved.

c. But if training practice changes because of TTFA performance analyses and recommendations, the TTFA will have made history. For the first time in 25 years the Army will have paid major, systematic attention to its well documented and potentially serious maintenance performance shortfall. Section 2.0 (including Table 1) summarizes the historical evidence. Section 3.0 outlines the recent analyses and recommendations.

2.0 HISTORY OF ARMY EVALUATIONS OF AUTOMOTIVE MAINTENANCE PERFORMANCE

2.1 In 1964 HumRRO tested 63C mechanics as they diagnosed and repaired "bugged" tanks, trucks, and personnel carriers in simulated work environments at Fort Knox and in combat organizational units (Smith, 1964). HumRRO staff recorded the number of failures to complete repair jobs and the number of mis-diagnoses. The mechanics failed to complete, correctly 81% of the assignments and mis-diagnosed 60 % of the problems (Schurman & Kern, 1981). In a similar study, but one using field observations of actual duties in organizational units, Applied Sciences Associates (ASA) found similar results: 84% of the assignments were not successfully finished (Schurman, Joyce, and Porsche, 1980).

2.2 The US Army Ordnance & Chemical Center (USAOCC), in 1978, tested the performance of 178 E1-E6 track vehicle mechanics (63Cs) and 167 tank automotive repairers(63Hs). Each soldier was tested on 8 tasks involving diagnosis, replacement, or adjustment. Percent of 63Cs failing ranged from 53% to 97%, across the 8 tasks. For the 63Hs, the failures ranged from 56% to 99%. These figures were combined with data on time-to-diagnose or repair and mean-time between failures to arrive at the conclusion that "the potential exists for equipment availability to fall to fifty percent or less for such critical items as the main battle tank."

2.3 The study above was repeated (same tasks and measures) by USAOCC on the National Guard. The figures for 63Cs were 78% to 100% failures. For 63Hs: 56% to 100% The same tasks were evaluated in both studies.

2.4 The Army Research Institute collected data from direct support maintenance shop records for one year (Dressel & Shields, 1979). It found that 42% of the parts replaced were falsely identified as defective. The percent of labor consumed by these false removals was 32%. If this figure is at all representative of the labor cost of deficient maintenance, it would be a matter of some concern in view of the $15+ billion per year which the Army spends on maintenance.

2.5 In 1981 Rand Corp. surveyed senior Army maintenance specialists from organizational, direct support, and general support units responsible for maintaining a variety of wheel and track vehicles (Harz, 1981). About 200 questions probed the existence of problems and ideas for solving the problems. Of particular interest was a query on false removals. The average estimate of rate of false removal was 36%, which is quite close to the Dressel and Shields (1979) more objective estimate of 42%.

2.6 The Army Research Institute (Kern & Hayes, 1983) showed widespread failures among 236 organizational wheel vehicle mechanics, on 5 different vehicles. 71% of the mechanics made one or more serious, uncorrected errors involving special tools or specifications, per maintenance activity. Experienced mechanics used the technical manual for 1% of their assignments, while inexperienced mechanics used the manuals for 12% of assignments. But even where TMs were used, failure rates were still very high. Of the mechanics who did use TMs (or other sources of information), 66% made one or more procedural errors per task compared to 79% for soldiers who did not consult a source of information.

2.7 In 1987, the TRADOC Analysis Command (TRAC) conducted a study similar to HumRRO's 1964 work and the studies by USAOCC in 1978. TRAC tested 63W and 63B performance on 5 tasks, using "bugged" wheel vehicles. The task failure rates ranged from 85% to 99%.

2.8 Added to the above are a number of studies done by ARI under the TTFA-Aberdeen program. These will be described in Section 3.0. But some illustrative results are shown in Table 1.

Additional studies of basic knowledges and skills (BKS) and task performance among 63W students and mechanics will be described in a contract report by Applied Sciences Associates (ASA), in preparation. However, a preliminary result of the BKS testing of 41 soldiers at the end of a 16-week course is that test items were failed, on average, by 56% of the students. The written test covered 6 diagnostic tasks and 1 replacement task selected by the instructors as critical.

Table 1. Army Studies of Automotive Maintenance Performance

When	Who	What	What Found
1964	HumRRO	Tested Track Vehicle Mechanics	81% of assignments Failed
1978	USAOCC	Determined Proficiency development profiles 63C and 63H MOSs	Potential for 50% down-time on Main Battle tank
1979	ARI	Collected data on M551 repairs	42% false removals. (32% of total labor)
1980	HumRRO	Observed TVMs	84% of assignments failed
1981	Rand	Surveyed Org.,DS & GS personnel.	37% false removals
1983	ARI	Observed Org.Mech., Ft. Knox	71% of assignments with serious errors. (Special tools/spec)
1987	TRADOC (TRAC)	Tested 63W&B performance in FORSCOM units	85 to 99% failure rates across 5 tasks
1988	TTFA (Ramsay)	Summarized end of course written test data by class	6 to 50% failure rates across classes
1988	TTFA (MacPher)	Predicted skill decay with ARI model	65% of soldiers fail injector pump removal, after 1 month.
1988	TTFA (ASA)	Tested end of course BKS. (contractor test)	56% average item failure rate, across 72 items for 7 tasks

3.0 ARI CONTRIBUTIONS TO THE TTFA-ABERDEEN PROGRAM

This review contains five sections: 3.1 Preliminary Review of the 63W Course; 3.2 Handbook for Producing Classroom Vugraphs; 3.3 Application of Skill Retention Model; 3.4 Development of Guidelines for Improving Skill Retention and transfer; and 3.5 Application of Resource Allocation Modeling to Phase 2 of the 63W10 course.

3.1 Preliminary Review of the 63W10 Course at Aberdeen Proving Ground (Ramsay, Kessler, Mirabella, & Thoreson, 1988).

a. The first effort of the TTFA was to observe Phases 1 (BKS) and 2 (task training) of the 63W10 course and to examine course grades. The reason for doing this was to gain first-hand knowledge about how training was currently being conducted and insights into how it might be improved. We maintained daily logs in which we described the training annex by annex and commented on possible training problems and solutions. An annex is a course segment lasting about two weeks.

b. To obtain quantitative data, we also compiled failure rates for samples of end-of-annex (EOA) and end-of-course (EOC) written tests. Data for 16 classes in Phase 1 are shown in Table 2. These are failure data for Annexes A through G. The highest failure rates occurred for Annexes C and E at 15% and 31 % respectively of all the students in those annexes. But the relatively low rates for the other annexes obscure very high failure rates for some classes within the annexes. For example, in the basic skills annex, 34% of the students failed in one class, though the average across all classes was only about 5%. Written test data from 8 classes in Phase 2 are shown in Table 3.

c. Use of Data.

(1) The data point to 3 topics for which revised training may be especially necessary: Introduction to engine systems, electrical technology, and hydraulic technology.

(2) The data plus course observations led to a set of preliminary recommendations for improving the 63W10 Wheel Vehicle Maintenance Course. One recommendation prompted the school to revise vugraphs used in the 63W Course and led the TTFA to develop a handbook on how to produce vugraphs.

d. Recommendations for improving the 63W10 course.

(1) Integrate basic skill and knowledge training (Phase 1) with MOS task training (phase 2). The separation of these two phases violates a fundamental of good instruction (TRADOC Pamphlet 600-11, Page 37, "Functional Context").

(2) Improve the visual side that support lectures, using the TTFA-developed guidebook on visual aids.

(3) Provide study guides for all annexes and copies of TM 9-800 for students to keep.

(4) If actual equipment (AE) examples are to be used during lectures, then provide one unit of AE per 2-3 students and pass them out beforehand so that instruction can be geared to the examples.

(5) Improve the quality of written tests by using professional test development techniques. An effort is needed which will produce the following.

a. Item pools
b. Item statistics
c. Alternate forms
d. Test statistics
e. Feedback to students

(6) Improve the quality of Phase 2 end-of-course performance tests by testing each student at all stations. Develop part-task testing methods so that it will be feasible to test all students at all stations.

(7) Use videotapes of experienced mechanics performing various tasks to give an overview and to illustrate the pace and style of on-the-job repair.

(8) Use computerized graphics and interactive video disc to:

help trainees grasp difficult or abstract concepts, e.g. electrical and hydraulic systems, use of micrometers, timing of diesel engines, engine cycles,

reduce student to actual equipment trainer ratios, and

increase student centered training.

(9) Add training on difficult maintenance conditions, e.g., "frozen" bolts, stripped threads, spilled fluids, accidents, fires.

(10) Obtain the benefits of both the team teaching method and in-place experts by assigning one or two "advisors" to each class instead of a team of 6-8 instructors.

Table 2. Performance Failure Data for 63W10 Course, Phase 1

	Annex	Failures	Mean Rate (%)	Min-Max (%)
A.	Common Subject	(40/560)	7.4	0.00-27.78
B.	Basic Skills	(30/557)	5.38	0.00-27.78
C.	Engine Systems	(166/530)	31.32	9.09-76.00
D.	Fuel, Air, Exhaust	(35/416)	8.14	0.00-22.50
E.	Auto Electricity	(64/410)	15.60	2.94-36.36
F.	Brake Systems	(20/367)	5.44	0.00-27.27
G.	Steering/Suspension	(10/368)	2.71	0.00-13.79

Table 3. Performance Failure Data for 63W10 Course, Phase 2

Annex	Failures	Mean Rates (%)	Min-Max (%)
J-6 Hydraulics/Electricity	(46/257)	17.89	6.66-30.00
N-1 End-of-Course Written Test	(55/257)	21.40	6.66-50.00

3.2 Handbook for Producing Classroom Vugraphs (Ramsay and Mirabella, 1988).

a. The 63W10 course review (Para. 3.1) showed that classroom vugraphs were often too detailed, not clearly tied to the teaching point, or were otherwise difficult to understand. To help the school improve its visual aids, we wrote 10 guidelines and procedures for producing vugraphs from already published materials.

b. The authors analyzed existing vugraphs and figures from the course textbook (TM 9-8000) for deficiencies. They then distilled a set of rules for how to improve visual materials and illustrated the rules with "before" and "after" examples. The rules are summarized in Table 4.

Table 4. Rules for Producing Classroom Vugraphs

1. Remove all unnecessary material from around the figure.
2. Make the figure reflect the main teaching point.
3. Eliminate unnecessary detail.
4. Reduce the number of call-outs to five or less.
5. Line up the call-outs.
6. Make call-outs cue words, not sentences or explanations.
7. Avoid using photographs.
8. Maintain correct spatial orientations.
9. Check for accuracy.
10. Test visual aids in the classroom.

3.3 Application of Skill Retention Model to 63W10 Tasks (Macpherson, Patterson, & Mirabella, in preparation)

a. The purpose of this project was to supplement data on maintenance performance in FORSCOM units, collected for TTFA, by Applied Sciences Associates (ASA). We applied ARI's skill retention model (Rose et al, 1985). This is an inexpensive way to estimate how quickly skills will decay for any specified task which is not practiced after training. The model, which provides pure measures of forgetting, can help interpret data on performance actually observed in units. We felt that the model could also be a useful tool at the US Army Ordnance School (USAOCS) for helping course developers prioritize tasks. We wanted to try it out on USAOCS subject-matter experts (SMEs) to see whether they could use it routinely.

b. The model includes a set of 10 scales which SMEs use to make judgements about task characteristics, e.g. how many steps does the task contain; what is the quality of the job aids used with the task. The SME answers each question (scale). Scale values attached to the answers are then added to provide a total which is used to enter a table. From this table, a forgetting curve is generated. Where several SMEs make different judgements that cannot be reconciled, different retention curves are generated. Multiple curves were prepared for three tasks: " engine cranks, doesn't start", "remove/ replace steering gear", and remove/replace injector pump". Which of the alternative curves should you use? Look for some outside evidence that supports one or the other. Otherwise, it's probably best to use the lower estimates of retention.

c. Results:

(1) Figures 1 and 2 show forgetting curves for tasks included in the ASA study. Figures 1 and 2 shows data for diagnostic tasks which ASA had originally planned to observe. Figure 2 shows the remove and replace tasks it was actually able to observe. From these curves we can prioritize tasks from most easily forgotten to most easily remembered. In fact TRADOC PAM 351-4(T) specifically tells you to do so as part of any front-end analysis. The model is a quantitative way to put the TRADOC guidance into practice. This guidance would lead us to put high priority for training "remove/replace injector pump" and "remove/replace steering gear",

(2) The model not only suggests what tasks may be problems, but also why they are problems, and how to improve performance. For example if a task is given a poor retention rating because its technical manuals are poorly written, the indicated solution might be to prepare easy-to-use job aids. Low ratings on the other scales would suggest other ways to improve performance.

(3) Furthermore, with the help of the scale values, we can even estimate how much improvement would result from changes suggested by the scales. For example, good quality job aiding could increase retention of injector pump skills from 2 weeks to 2 months. If we combine that information with the cost of the improvement, we can estimate "how much a pound of training is worth". ARI reports by Adams (1985) and Thoreson (1988) contain useful ideas and procedures on how to do cost-effectiveness trade-offs. The Skill Retention Model supplies the performance data we have always lacked to do such trade-offs.

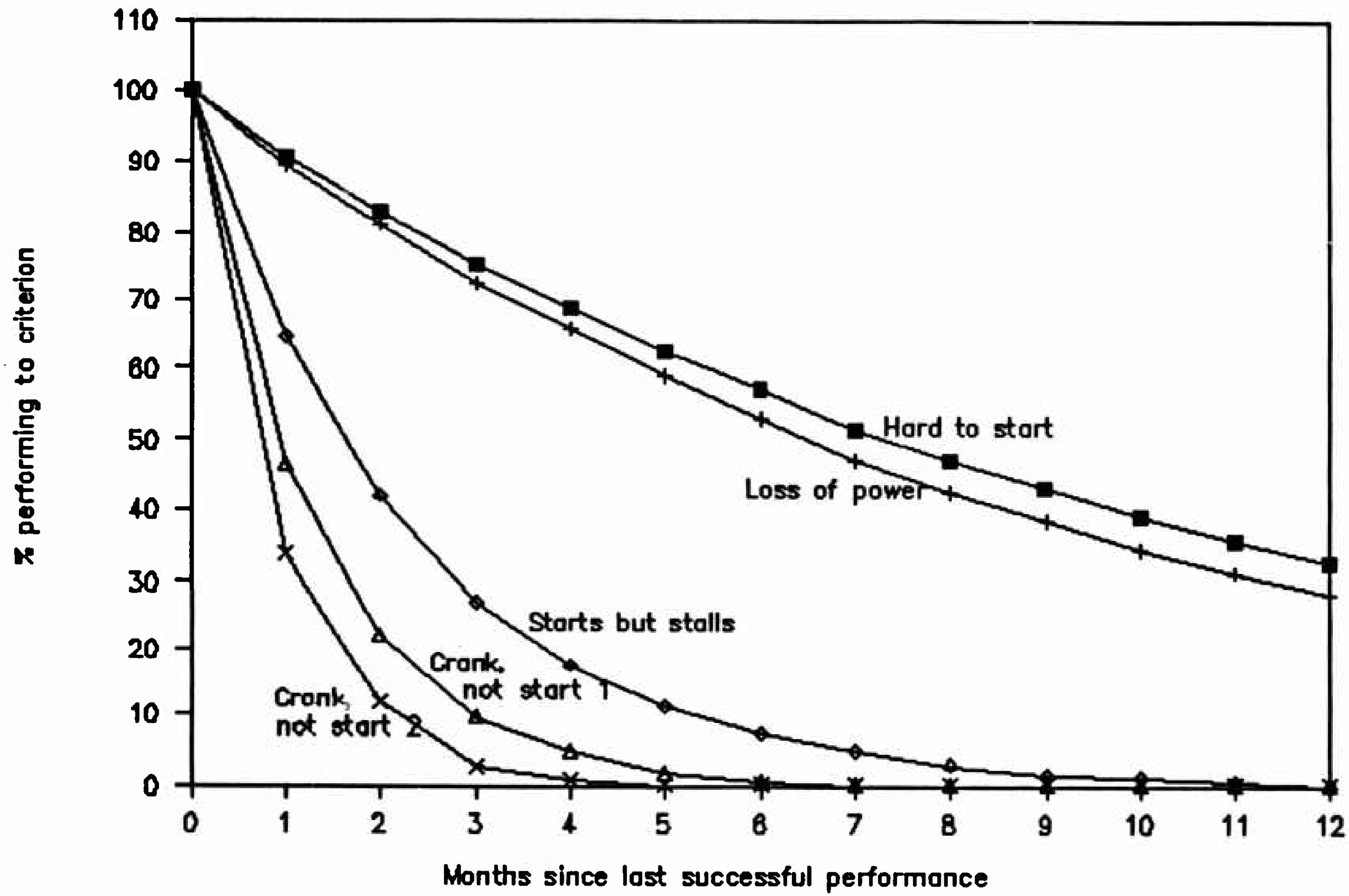

Fig 1. Predicted engine diagnostic performance

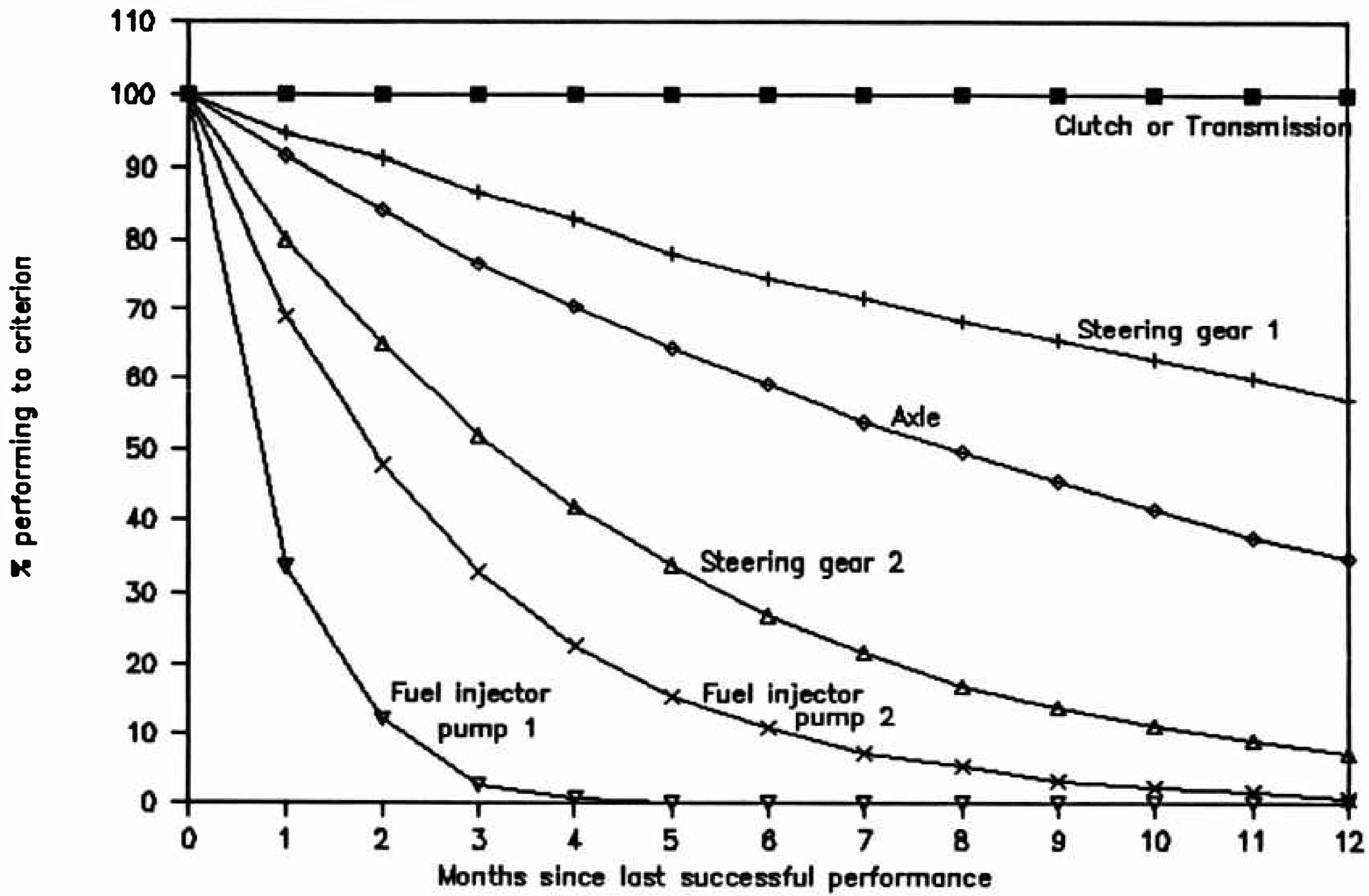

Fig 2. Predicted remove/replace performance

d. Value of the Skill Retention Model. The model is particularly useful because it can generate performance predictions quickly and inexpensively. We were able to collect data for 10 63W10 tasks in two days. The empirical study by ASA will generate data for 5 tasks, at a contract cost of $200,000, over 9 months. The empirical study was essential for TTFA purposes and could not have been avoided. But because field studies are so expensive and time consuming they cannot be used routinely for front-end analysis. The Skill Retention Model can, in production use, process tasks at the rate of one per hour and therefore provides a feasible quantitative tool to support the task prioritization called for by TRADOC PAM 351-4(t).

e. Project Conclusions: The Skill Retention Model can:

(1) be administered to SMEs at the Ordnance School,

(2) flag tasks which are easily forgotten,

(3) show task features which "cause" skill decay,

(4) point to training fixes,

(5) support cost-training effectiveness analysis.

3.4 Development of Guidelines for Improving Skill Retention & Transfer Among 63W10 Repairers (Mirabella, Macpherson, & Patterson, in preparation).

a. The project was aimed at supporting an evaluation of maintenance performance in FORSCOM units. That evaluation, done under contract by ASA, was designed to uncover performance deficiencies, but not necessarily to provide training solutions. Therefore, we attempted to produce a general set of training development principles based on a review of research literature, TRADOC PAM 600-11, and the TRADOC sponsored Harless Workshop. Furthermore, we expected to apply those principles to a 63W10 task, using "before" and "after" examples in the manner of the vugraph handbook. We were not able to pursue the application because ARI withdrew from the TTFA-Aberdeen. But we recommend that ASA consider the principles in completing its last contractual task which is to develop a training solution strategy for deficiencies found in its front-end analysis.

b. Results: We generated 10 principles, a large number of corollaries, explanations for each, and guidance on how to put the principles into practice. The principles are summarized in Table 5.

c. Project Conclusions:

(1) Maintenance performance deficiency is a significant, but predictable problem in the Army,

(2) Techniques exist to reduce these deficiencies to a negligible amount,

(3) The techniques are fully compatible with TRADOC REG 71-2, PAM 600-11, and PAM 351-4(T),

(4) They are condensed in the principles generated by this project,

(5) They are not currently being used, or they are being used incorrectly,

(6) To use them effectively we need to shift from a lecture/content-oriented style of training to one that is workshop/task-oriented.

Table 5. Principles for Improving Skill Acquisition, Retention and Transfer for 63Ws.

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1. Identify and prioritize problem tasks. Use the ARI Skill Retention Model, along with any available performance evaluation data.

2. Identify problem steps within tasks. Tasks are often failed because one or two steps are difficult. Give these special attention.

3. Integrate Basic Knowledge and Skills with task training, i.e. Phase 1 and 2 of the 63W10 Course. Doing so would conform to the principles of functional context training specified in TRADOC PAM 600-11.

4. Replace the current lecture/content oriented philosophy with a workshop/task orientation. This is also consistent with the functional context principles specified in TRADOC PAM 600-11. (See also the ARI Guidebook for the Development of Army Training Literature).

5. Use the basic rule of good instruction from the TRADOC-sponsored Harless Workshop: the 5 Ps.

a. Prime: Explain/demonstrate/check for comprehension
b. Prompt: Give part-task training with help
c. Perform: Give part-task training with reduced help
d. Isolated Practice: Give whole task training
e. Integrated Practice: Combine whole task with related tasks

6. Raise test standards and improve performance testing. The more effectively soldiers learn, the slower they forget. Raise the passing grade from 70% to 85%, and increase remedial training accordingly.

7. Sequence training from general to specific information, concrete experience to abstract ideas, and familiar to unfamiliar material.

8. Use specialized part-task techniques, e.g

a. Break-up long tasks
b. Provide extra practice for hard steps like difficult decisions
c. Use "deep processing", e.g. analogies, mnemonics, probe questions.

9. Train for transfer to new equipment as well as retention, e.g.

a. Train to proficiency (i.e. to standards) on a particular task
b. Repeat practice 1 to 3 times beyond proficiency (overtrain).
c. Spread practice over 3 to 5 days

10. Improve job aiding/TM training.

a. Focus on multi-TM tasks (these are most difficult)
b. Develop easy-to-use job aids for most difficult tasks or steps

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3.5 Application of Resource Allocation Modeling to Phase 2 of the 63W10 Course (Kessler, in preparation).

a. During our observation of the 63W Course, Phase 2, we noticed that actual equipment trainers (AETs) were idle about 50% of the time. Yet the student to AET ratio was often high, some students did not participate fully in group exercises, and tasks were practiced only once. We saw an opportunity for using AETs much more efficiently. The TTFA-Ft Rucker had reported success using a computer -based model to allocate (i.e. schedule) training resources efficiently. We decided to see whether the Rucker model could be used at the Ordnance School.

b. We saw demonstrations of the Rucker Model and reviewed its documentation. We also examined course scheduling problems at Rucker. Conclusion: the specific Rucker model is not exportable to USAOCS because scheduling problems are unique at the Aviation School. Course modules there are sequence dependent, constrained by weather, and involve match-ups between instructors, students, and specific AETs (helicopters). But MICROSAINT, a simulation program underlying the Rucker model, could be used at Aberdeen, not only to improve efficiency in training, but also to automate portions of the scheduling task in Phase 2 of the 63W10 course. MICROSAINT is a high level programming language which simulates networks of events or tasks. It is designed to solve resource allocation and scheduling problems.

c. Figure 4 shows how we used MICROSAINT to simulate Phase 2 of the 63W10 course. We told the computer which classes were entering Phase 2, and in what sequence. We also identified the annexes and times to complete them. We instructed the computer to assign each incoming class to an "empty" annex, and then reassign it to the next one available after the first one was completed. The result of the simulation was a chronological list of class assignments with begining and ending times for each annex.

d. Unfinished business. We've tried to show an opportunity for making 63W10 training more cost-effective and to demonstrate how to do so. To finish this work, a number of things have to be done.

(1) The output format of our simulation is not user-friendly. It consists of a list of class by annex assignments. The information needs to be formatted as a calender of events, so that the user can clearly see who goes where, and when. This may require the use of additional programming capability, e.g. a spread sheet or a data base.

(2) MICROSAINT is not easy to use. Someone needs to create a job aid for routine users not steeped in the software.

(3) But first someone who knows both MICROSAINT and the 63W10 scheduling requirements needs to program and experiment with various rules and constraints to optimize the use of AETs in Phase 2. e.g sub-grouping of classes to reduce class size, duration of lessons within annexes, sequence dependencies among lessons or annexes, number of AETs, number of instructors. For example, suppose you told the computer to divide incoming classes into groups and then to randomly assign groups to "empty" lessons or annexes, what effect would that have on AET idle time and student to AET ratio?

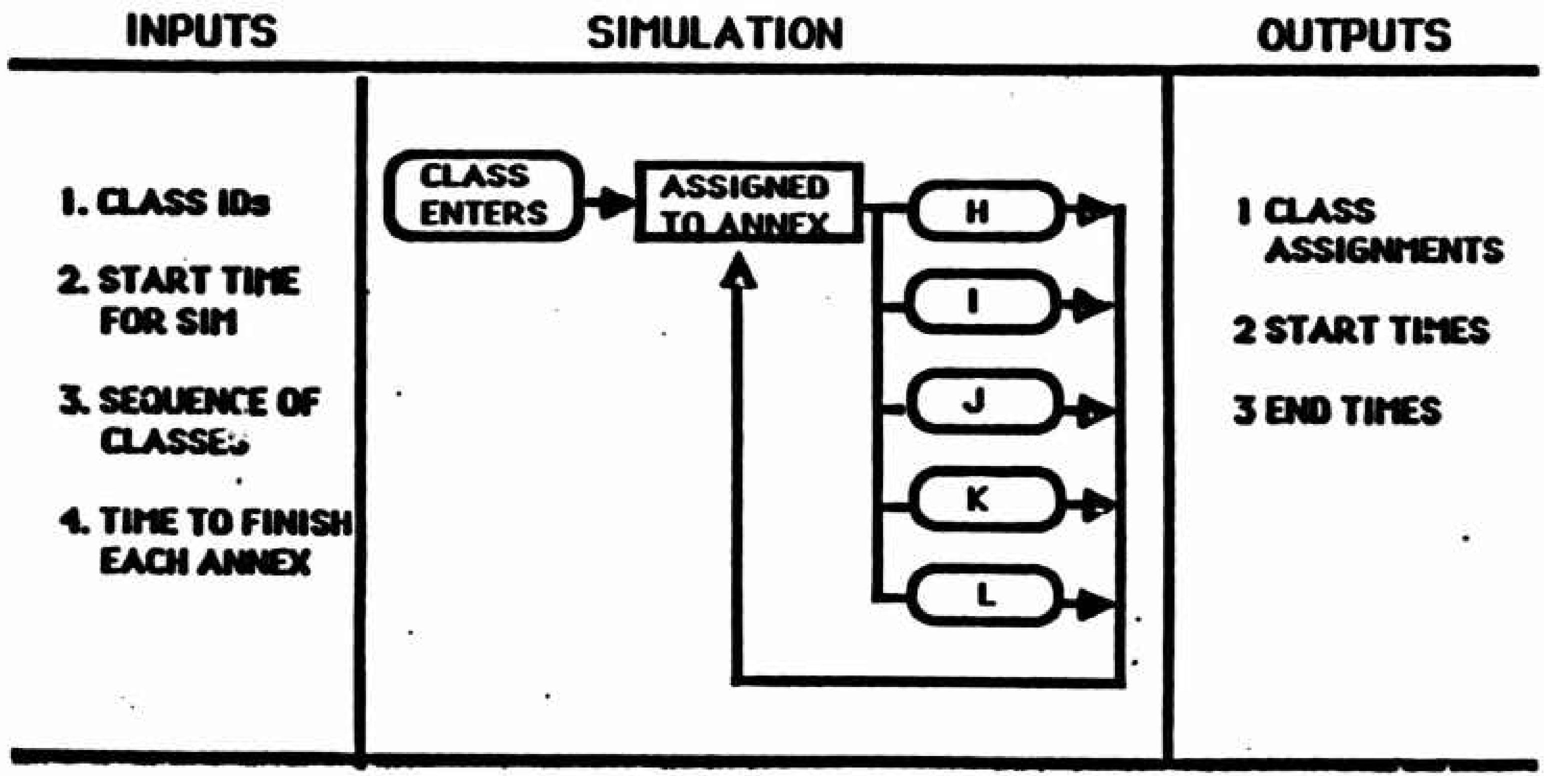

FIG.3. RESOURCE ALLOCATION MODELING DEMONSTRATION OF PHASE 2 SIMULATION

d. Value of MICROSAINT. Given a 50%, or even smaller idle time for AETs and a price tag of $22,000 per student in the 63W10 Course, the pay-off for more efficient use of training resources could be very substantial. With the time saved, the Ordnance School could apply some of the methods recommended by other TTFA projects to improve skill acquisition, retention, and transfer.

4.0 CONCLUDING COMMENTS

4.1 The TTFA has the potential for some very exciting opportunties to help the Army improve the way it conducts its maintenance training business. The potential changes would not be easy to implement, but they could be brought about in modest, and measured stages. Working with the test-bed course and a few carefully selected tasks, it should be possible for the TTFA to demonstrate how ideas for improving skill acquisition, retention and transfer might be implemented.

4.2 Testing ideas should be an important part of the TTFA program. While the recommendations that have emerged over the past two years are based on scientific evidence and have worked elsewhere, they may still not be appropriate to, or effective for, the Ordnance School. Those ideas which prove to be effective in well-designed evaluations can then be extended to other parts of the 63W10 course, as well as to other courses. The potential payoffs for even modest successes are large, given the $22,000 per student price tag for the 63W10 Course and the $15+ billion spent yearly by the Army on maintenance.

4.3 Implementing the proven ideas, particularly those based on the functional context training principles of PAM 600-11, could involve major changes in course design and management. However, the changes could be phased in gradually. For example, if BKS and task training were to be integrated, the first step might be to reschedule some of the annexes so that related annexes in Phases 1 and 2 are close to each other instead of being separated by 5 or 6 weeks.

4.4 The Skill Retention Model should be used by TRADOC to develop guidelines on refresher training in operational units.

4.5 In closing, the TTFA-Aberdeen has been a succesful ground-breaking effort. The three partners, USAOCS, Training Development and Analysis Division (TDAD) of TRADOC, Fort Monroe, and ARI, working together, have been productive and have made significant contributions. It is recommended that this model of R&D coupled to implementation be continued.

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